THE RECONSTITUTION: ENVIRONMENTAL RESTORATION ASSESSMENT BY MEANS OF LCC AND FCC

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Abstract

The reconstitution is a pedotecnique producing environmental proper and fertile Technosols, applying chemical-mechanical treatment to alluvial sediments, degraded soils and pedomaterials included waste by different productive processes. By means of reconstitution, the environmental restoration of the covering degraded soil of a closed landfill near Piacenza is made (LIFE10 ENV/IT/000400 NEW LIFE). In order to assess this environmental restoration, LCC and FCC are calculated on 5 soil samples before and after reconstitution. The results, which highlight the transition from worst to best LCC and FCC classes show how reconstitution was able to convert the environmental and agronomic conditions from soil have very severe limitations that restrict the choice of plants or require very careful management, and that limit or restrict its use mainly to pasture, range, forestland, or wildlife food and cover, to soil have moderate limitations that restrict the choice of plants or that require moderate conservation practices or have optimum fertility.

Keywords: *reconstituted soil, LCC, FCC*

Introduction

Land degradation and desertification are severe danger for soil - one of main, non-renewable resources insuring food production and ecosystems balance.
Pedotechnologies are technologies aimed to design appropriate actions to restore land according to their expected use or to create ad hoc soils, using suitable materials from anthropic activities. These soils are called "anthropogenic". The World Reference Base for Soil Resources (WRBSR) presented in 2006 Technosols Reference Soil Group to classify soils dominated or strongly influenced by human activity by defining them as soils "containing significant quantities of artefacts and whose properties and pedogenesis are dominated by their origin" (IUSS Working Group WRB 2006). Considering reconstituted soils, they are generated by a targeted chemical-mechanical treatment of several measured matrices, and not only by the single mixing of the different components, in this way reconstituted soils properties are different from that resulting by the simple mixture of components.

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Reconstituted soils properties are the result of reconstitution: based on composition and targeted succession of chemical-mechanical actions on the mixture, losing the characters of the original materials used. This is crucial to discriminate reconstituted soils from Technosols produced by simple matrices mixing.

Reconstitution is a pedotechnology able to produce great amount of soil from degraded and sterile soils, producing Technosols with chemical and physical fertility.

Materials environmental and agronomical suitable - called pedotechnomaterials (Capra et al., 2015) are used in reconstitution: these include waste from industrial activities analyzed on each individual production process and subjected to meticulous procedures check.

To valuate a soil environmental or agronomic restoration there is the need to compare soil characters before and after intervention, through soil chemical-physical analyses, agronomic tests and using indices to determine the soil quality.

Indices of soil quality and fertility are the evaluations of physical, chemical and biological characters thanks to soil is a means to sustain plants life and to provide ecosystem services. Indices must provide useful answers for management and must be correlated with plant growth.

Land Capability Classification (LCC, Klingebiel e Montgomery, 1961) is used to classify lands not based on specific cultures or agricultural practices but for large agro-pastoral systems (Costantini, 2006). LCC does not refer only to soil physical properties, which determine its more or less attitude for crops, as regards the limitations to agricultural use in general; limitations that also derive from the quality of the soil, but above all from the environment in which it is. The limitation constituted by the low productivity, linked to soil chemical fertility parameters (pH, CEC, organic matter, salinity, saturation in bases) is related to the physical landscape (morphology, climate, vegetation) that they give to the same limitation a different intensity depending on whether these requirements are permanently unfavourable or not (Curtaz et al., 2013). Fertility Capability Classification (FCC, Sanchez et al., 1982) evaluates the soil fertility, not in relation to morphology or evolution, but based on the physico-chemical properties of the top soil (0-20 cm). FCC is a technical system for grouping soils according to the kinds of problems they present for agronomic management of their chemical and physical properties. It emphasizes quantifiable topsoil parameters as well as subsoil properties directly connected to plant growth. FCC classes indicate the main fertility-related soil constraints, which can be interpreted in relation to specific farming systems or land utilization types (Sanchez, et al., 1982). In judging about soil agricultural attitude, FCC highlights the limiting factors for the development of plants and it is applicable on a large scale; however, it must be kept in mind that this system has been studied for application in the agricultural field and therefore some of these factors are limiting for agricultural species, but not for forestry ones (Curtaz et al., 2013). Francaviglia et al., 2004 have proposed an FCC review that allows, on the basis of chemical-physical laboratory parameters (texture, pH, organic matter, total limestone, exchangeable K and available P), to calculate an indicator of total soil fertility.

Materials

The reconstitution technology

Reconstituted soil is a Technosol produced by reconstitution. The reconstitution is a patented pedotechnique designed to act on two types of soils: on soils that have been profoundly modified from their original condition and agricultural soils that have undergone agronomic and environmental deterioration (Manfredi, 2016). By the means of this pedotechique chemical and mechanical process are applied to soil restoring its fertility and allowing the production of a greater quantity of soil using environmental and pedological suitable materials. The reconstitution is an interesting applying method since it does not generate a mixture of different components but, through the proper processing of the mixture, changes their nature by breaking down and recomposing them into new aggregates with specific properties. At the hearth of reconstitution there is the organic matter incorporation into soil mineral fraction (Manfredi, 2016). In the first phase soils are mixed with alluvial sediments and pedomaterial - including waste from different production processes - previously characterized and dosed on the basis of their chemical-physical properties. The mixing is followed by a disintegration, which involves a loss of the structural matrices characters. Then there is the incorporation of organic matter, from added matrices, into the mineral fraction, followed by a stabilization treatment and finally a mechanical reconstitution (Manfredi, 2016). After identifying the area to be restored, the soil is moved, brought to the threating area, reconstituted and took back to the area for a greater thickness than the original one.

In this manuscript it is described the environmental restoration of a closed landfill near Piacenza. This restoration has been founded by the European Community (LIFE10ENV/IT/000400 NEW LIFE; http://www.lifeplusecosistemi.eu).

Study area

The study area is 20 hectares site, located in Campo Santo Vecchio (Borgotrebbia) in the municipal territory of Piacenza (Emilia-Romagna, Italy). The site, from 1972 to 1985, was a landfill of solid urban waste. Waste was arranged in all the area for a thickness of 4 - 5 meters and covered with less than 30 cm of human transported materials: it appeared as a flat relief of waste covered by a layer of earthy materials of various origins. Potential vegetation of the area is the riparian woods of *Populetalia albae* (Br.-Bl.) 1935 with oaks and hornbeams (Ferrari 1997; Puppi et al., 2010). The area was degraded, covered with spontaneous ruderal vegetation, typical of poor structure soils, poorly drained and with water content varying according to the season. It made undergone to intense pasture and only marginally used by the population (Giupponi L. et al., 2013). In this area reconstituted soils were used to carried out an environmental restoration. The covering soils, before being reconstituted, have been characterized. 52 soil samples were sampled on the basis of vegetation or morphological aspects. After characterization, covered soil was moved, brought to the reconstitution site, treated and then took back to the closed landfill.

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Then the area has been planted with arboreal and shrubby species whose development is being monitored. Reconstituted soils are sampled regularly to check chemical-physical parameters. In order to describe the effectiveness of the restoration, the LCC and the FCC were determined on 5 samples before and after the intervention (Figure 1).

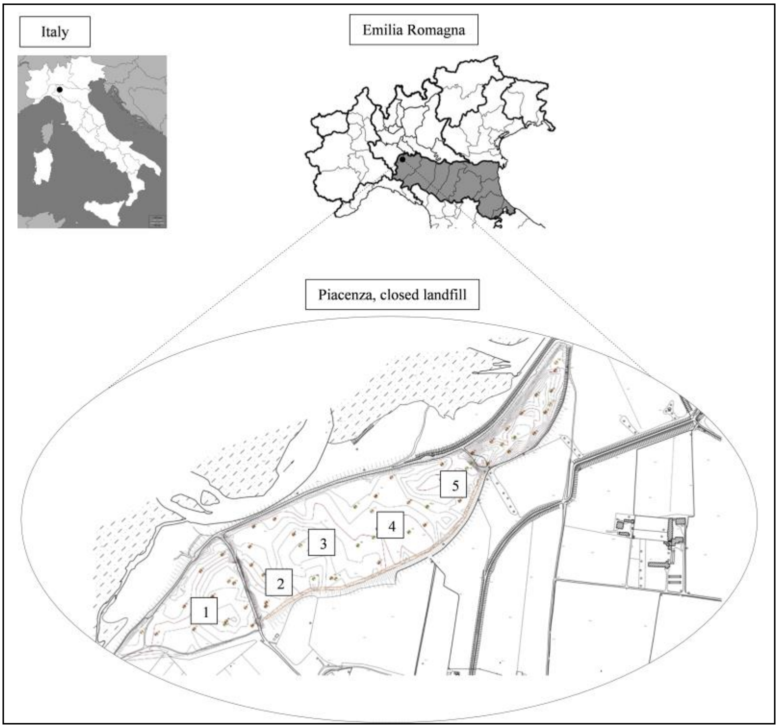

Figure 1
Sample point in closed landfill.

1: N 45°03’54”, E 09°38’57”

2: N 45°03’55”, E 09°39’01”

3: N 45°03’57”, E 09°39’09”

4: N 45°03’58”, E 09°39’11”

5: N 45°03’60”, E 09°38’17”

Methods

Land Capability Classification (LCC)

Land Capability Classification (LCC) is developed by the Soil Conservation Service of United States Department of Agriculture (Klingebiel and Montgomery, 1961). It has been widely used throughout the world. This is a categorical system based on qualitative estimation criteria.

The classification provides eight classes defined by the combination between choice of use and intensity of the limitations (Table 1): from the first to the eighth class there is an increase in the number and degree of limitations and the choice of productive uses is restricted.

LCC does not refer only to soil physical properties, which determine more or less attitude in the choise of crops, but also to limitations for agricultural use; limitations that derive from the soil quality, but also from the environment. The limitation constituted by the low productivity, linked to parameters of soil chemical fertility (pH, CEC, organic matter, salinity, saturation in bases) is related to physical landscape (morphology, climate, vegetation) that make the same limitation assume a different degree of intensity depending on whether they are permanently unfavourable or not (Curtaz et al., 2013) (Table 2, 3).

Table 1 *Description of LCC classes.*

I	soils have slight limitations that restrict their use
II	soils have moderate limitations that restrict the choice of plants or that require moderate conservation practices
III	soils have severe limitations that reduce the choice of plants or require special conservation practices, or both
IV	soils have very severe limitations that restrict the choice of plants or require very careful management, or both
V	soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover
VI	soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover
VII	soils have very severe limitations that make them unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife
VIII	soils and miscellaneous areas have limitations that preclude their use for commercial plant production and limit their use to recreation, wildlife, or water supply or for esthetic purposes

Table 2. *Valuation of LCC classes.*

	LCC classes							
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
Root restricting layer (cm)	**> 100**	**> 100**	**50 - 100**	**25 - 49**	**25- 49**	**25-49**	**10-24**	**< 10**
Texture (USDA) *	**S; LS; SL; L; CL**	**Si; SiL; SC; SCL; SiCL; C**	**SiC**	**-**	**-**	**-**	**-**	**-**
Parent material (%)	**< 5**	**5 - 15**	**16 - 35**	**36 - 70**	**> 70**	**> 70**	**-**	**-**
Gravel (%)	**< 0.3**	**0.3 - 1**	**1.1 - 3**	**3.1 - 15**	**> 15**	**15.1-50**	**15.1-50**	**> 50**
Stoniness (%)	**0**	**0**	**< 2**	**2.1 - 10**	**> 10**	**10.1-25**	**25.1-50**	**> 50**
Chemical fertility	**Table 3**							
Salinity (dS m^{-1})	**< 2**	**2 - 4**	**2.1 - 8**	**> 8**	**-**	**-**	**-**	**-**
Slope (%)	**< 13**	**14 - 20**	**21 - 35**	**36 - 60**	**-**	**36-60**	**61-90**	**> 90**
Erosion risk	**no**	**common moderate**	**common moderate canalized; common eolian**	**erosion from collapse or hilly erosion**	**-**	**-**	**-**	**-**
Climatic limitation	**no**	**light**	**moderate**	**no moderate**	**no moderate**	**strong**	**very strong**	**-**

***** S: Sand; LS: Loamy Sand; SL: Sandy Loam; L: Loam; CL: Clay Loam; Si: Silt; SiL: Silt Loam; SCL: Sandy Clay Loam; SiCL: Silty Clay Loam; SC: Sandy Clay; C: Clay; SiC: Silty Clay.

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Class	pH	C.E.C. (meq 100 g^{-1})	$CaCO_3$ (g kg^{-1})
I	6.6 - 8.4	> 10	< 400
II	5.6 - 6.5	5 - 10	> 400
III	4.5 - 5.5; > 8.4	< 5	any
IV	< 4.5	any	any
V	any	any	any
VI	any	any	any
VII	any	any	any
VIII	any	any	any

Table 3
Valuation of LCC chemical fertility.

Fertility Capability Classification (FCC)

Soil Fertility Capability Classification (FCC) is proposed by Buol et al. (1975) and modified by Sanchez et al. (1982, 2003). This is a system to classify soil in groups with a homogeneous chemical fertility. There are three levels: the first is defined by texture of the top soil; the second by texture of bulk soil (within 50 cm); the third by "specifiers" representing chemical and physical conditions that can negatively affect fertility - water content, toxic elements, salinity, etc. In the review by Sanchez et al. (2003) FCC is proposed as a semi-quantitative soil quality estimation system. (Costantini 2006).

Francaviglia et al. (2004) proposed a review of FCC that allows, on the basis of chemical-physical parameters (texture, pH, organic matter, total limestone, exchangeable K_2O, P_2O_5), to calculate a total fertility indicator. Total soil fertility (Table 4) is made by two sub-models.

Total Fertility				
Intrinsic	**Fertility**	**A**	**B**	**C**
Chemical Fertility	1	I	I	II
	2	I	II	III
	3	II	III	III
	4	IV	IV	V
	5	IV	V	V

Table 4
Valuation of total soil fertility in FCC; total fertility decreases from I to V

The first sub-model defines chemical fertility; it is calculated by texture, exchangeable K_2O, P_2O_5 and pH (Table 5).

In chemical fertility model, texture is divided into three macro classes: sandy soils (S>60%), loam soils and clayey soils (A >35%). This division is useful to describe the endowment of nutritive elements: to sandy soils - theoretically more lacking than loamy and clayey soil - it is attributed a threshold of sufficiency lower than that of other textures, and the same considerations are for the loamy compared to clayey ones. K_2O and P_2O_5 are divided into sufficiency thresholds in relation to texture. The last division is related to pH.

Table 5. *Valuation of soil chemical fertility in FCC; chemical fertility decreases from 1 to 5.*

K_2O (mg kg^{-1})		< 80			80 - 100			101 - 120			121 - 160			>160		
	pH	< 5.0 >8.5	5.0 - 6.5 7.9 - 8.5	6.6 - 7.8	< 5.0 > 8.5	5.0 - 6.5 7.9 - 8.5	6.6 - 7.8	< 5.0 > 8.5	5.0 - 6.5 7.9 - 8.5	6.6 - 7.8	< 5.0 > 8.5	5.0 - 6.5 7.9 - 8.5	6.6 - 7.8	< 5.0 > 8.5	5.0 - 6.5 7.9 - 8.5	6.6 - 7.8
Texture	P_2O_5 (mg kg^{-1})															
sand >60 %	< 23	5	5	4	5	4	4	4	3	3	4	3	3	4	3	3
	23 - 30	4	4	3	4	3	3	4	3	2	3	2	2	3	2	1
	31 - 34	4	3	3	3	2	2	3	2	1	3	1	1	3	2	1
	> 34	3	3	3	3	2	2	3	2	2	3	2	2	2	2	2
loam	< 30	5	5	5	5	5	5	5	4	4	4	3	3	4	3	3
	30 - 39	5	4	4	5	4	4	4	3	3	4	2	2	3	2	1
	40 - 48	4	3	3	4	3	3	3	2	2	3	1	1	3	2	1
	> 48	4	3	3	4	3	3	3	2	2	3	2	2	3	2	2
clay > 35 %	< 34	5	5	5	5	5	4	5	4	4	5	4	4	4	3	3
	34- 44	5	4	4	5	4	4	4	3	3	4	3	3	4	3	1
	45 - 55	4	4	3	4	4	3	4	3	3	3	2	2	3	2	1
	> 55	4	3	3	4	3	3	3	3	3	3	2	2	3	2	2

The second sub-model defines soil intrinsic fertility; it is calculated by organic matter in relation to the annual mineralization coefficient, which in turn depends on clay and total limestone (Table 6) (Francaviglia et al., 2004). In this manuscript it is used the reviewed by Francaviglia et al. (2004).

Intrinsic Fertility	
N	Class
< 2	C
2 - 4	B
> 4	A

Table 6
Valuation of soil intrinsic fertility in FCC; intrinsic fertility decreases from A to C

Soil analyses

Every soil sample (0-20 cm) for physical and chemical analysis was made of three sub-samples. Physical-chemical analyses were performed on air-dried < 2 mm soil according to the Official Italian procedures. Texture follow MiPAF (1997); chemical analysis (pH, soil salinity, organic C, $CaCO_3$, CEC, exchangeable K and P Olsen) follow MiPAF (2000). Sand (2.0 - 0.02 mm), silt (0.02 - 0.002 mm) and clay (< 0.002 mm) fractions were separated by the hydrometer method, and textural class was defined according to USDA (Soil Survey Laboratory Staff, 2004). pH was measured on 1:2.5 soil/water mixtures. Soil salinity was measured by determining the electrical conductivity of a saturated paste extract. Organic carbon was oxidized with dichromate potassium and titrated (Walkley-Black, 1934).

Total limestone was determined using calcimeter method. CEC and Exchangeable K were determined using $BaCl_2$, triethanolamine, pH 8.1 method. P was determined by Olsen method. K_2O, P_2O_5, organic matter mineralized in 1 year K (Rémy and Marin-Laflèche, 1974) and number of year for mineralization of organic matter N were calculated.

$$K = \frac{1200}{(\text{clay}\ \% + 20) \times (CaCO_3\ \% + 20)} \qquad [1]$$

$$N = \frac{\text{organic carbon}\ \%}{K} \qquad [2]$$

Further observations have been made in field describing surface characters: root restricting layer, parent material, gravel, stoniness, slope, erosion risk, climatic limitations.

Based on the analytical outcomes and field observations, LCC and FCC classes were determined before and after the reconstitution.

Results

Area before reconstitution

Tables 7, 8, 9 the FCC and LCC classes are presented before and after the intervention; in Table 1 and 4 there are classes description.

Root restricting layer was more reduced than the soil thickness, the lower limit of soil was wavy and in direct contact with waste (demolition aggregates, slag and foundry sands, plastics and organic and inorganic muds). Frequent cracks in the soil both linked to the superficial crusts or affected the soil layer.

In area 1 roots restricting layer was 35 cm, parent material 12 %, gravel 6.5 %, stoniness 0, slope < 0.2 %, no erosion risk or climatic limitations. Soil was moderately alkaline pH 7.9, salinity was 0.2 dS m^{-1}; cation exchange capacity was 19.7 meq $100g^{-1}$; exchangeable potassium K_2O was 82 mg kg^{-1}; total limestone was 38 g kg^{-1}; organic carbon content was 1.7 %; phosphorus content P_2O_5 was 99 mg kg^{-1}. Texture was loamy, 15 % clay. Organic matter mineralized in 1 year was 1.5 %; complete mineralization of organic matter was 1.1 years. In this area factors determining LCC class were roots restricting layer and gravel: LCC class IV, other parameters: LCC classes I and II.

In FCC intrinsic fertility was class C, chemical fertility was class 3; total fertility was class III.

In area 2 roots restricting layer was 26 cm, parent material 18 %, gravel 5 %, stoniness 0, slope < 0.2 %, no erosion risk or climatic limitations. Soil was moderately alkaline pH 7.5, salinity was 0.3 dS m^{-1}; cation exchange capacity was 12.1 meq $100g^{-1}$; exchangeable potassium K_2O was 95 mg kg^{-1}; total limestone was 55 g kg^{-1}; organic carbon content was 2.7 %; phosphorus content P_2O_5 was 48 mg kg^{-1}. Texture was loamy, 12 % clay. Organic matter mineralized in 1 year was 1.5 %; complete mineralization of organic matter was 1.8 years. In this area factors

determining LCC class were roots restricting layer and gravel: LCC class IV, other parameters: LCC classes I, II and III.
In FCC intrinsic fertility was class C, chemical fertility was class 3; total fertility was class III.
In area 3 roots restricting layer was 24 cm, parent material 37 %, gravel 28 %, stoniness 0, slope < 0.2 %, no erosion risk or climatic limitations. Soil was moderately alkaline pH 7.9, salinity was 2.0 dS m^{-1}; cation exchange capacity was 8.5 meq $100g^{-1}$; exchangeable potassium K_2O was 98 mg kg^{-1}; total limestone was 130 g kg^{-1}; organic carbon content was 1.9 %; phosphorus content P_2O_5 was 18 mg kg^{-1}. Texture was loamy, 12 % clay. Organic matter mineralized in 1 year was 1.1 %; complete mineralization of organic matter was 1.7 years. In this area factors determining LCC class were roots restricting layer and gravel: LCC class VII, other parameters: LCC classes I, II and IV.
In FCC intrinsic fertility was class C, chemical fertility was class 5; total fertility was class V.
In area 4 roots restricting layer was 35 cm, parent material 12 %, gravel 6.2 %, stoniness 0, slope < 0.2 %, no erosion risk or climatic limitations. Soil was moderately alkaline pH 8.1, salinity was 0.2 dS m^{-1}; cation exchange capacity was 32.2 meq $100g^{-1}$; exchangeable potassium K_2O was 99 mg kg^{-1}; total limestone was 138 g kg^{-1}; organic carbon content was 2.3 %; phosphorus content P_2O_5 was 139 mg kg^{-1}. Texture was loamy, 12 % clay. Organic matter mineralized in 1 year was 1.1 %; complete mineralization of organic matter was 2.1 years. In this area factors determining LCC class were roots restricting layer, parent material and gravel: LCC class IV, other parameters: LCC classes I and II.
In FCC intrinsic fertility was class B, chemical fertility was class 3; total fertility was class III.
In area 5 roots restricting layer was 22 cm, parent material 25 %, gravel 6.8 %, stoniness 0, slope < 0.2 %, no erosion risk or climatic limitations. Soil was moderately alkaline pH 8.0, salinity was 0.1 dS m^{-1}; cation exchange capacity was 15.9 meq $100g^{-1}$; exchangeable potassium K_2O was 82 mg kg^{-1}; total limestone was 60 g kg^{-1}; organic carbon content was 2.7 %; phosphorus content P_2O_5 was 80 mg kg^{-1}. Texture was loamy, 10 % clay. Organic matter mineralized in 1 year was 1.5 %; complete mineralization of organic matter was 1.7 years. In this area factors determining LCC class was root restricting layer: LCC class VII, other parameters: LCC classes I, II, III and IV.
In FCC intrinsic fertility was class C, chemical fertility was class 3; total fertility was class III.

Area after reconstitution

Tables 7, 8, 9 the FCC and LCC classes are presented before and after the intervention; in Table 1 and 4 there are classes description.
In area 1 roots restricting layer was > 150 cm, parent material < 5 %, gravel < 0.3 %, stoniness 0, slope < 0.2 %, no erosion risk or climatic limitations. Soil is

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slightly alkaline pH 7.8; salinity is 0.8 dS m^{-1}; cation exchange capacity is 31.2 meq $100g^{-1}$; exchangeable potassium K_2O is 199 mg kg^{-1}; total limestone is 124 g kg^{-1}; organic carbon content is 4.7 %; phosphorus content P_2O_5 is 104 mg kg^{-1}. The texture is loamy, 11 % clay. Organic matter mineralized in 1 year is 1.0 %; complete mineralization of organic matter is 4.5 years. In this area factors determining LCC class is texture: LCC class II, other parameters: LCC class I.
In FCC intrinsic fertility is class A, chemical fertility is class 2; total fertility is class I.
In area 2 roots restricting layer was > 150 cm, parent material < 5 %, gravel < 0.3 %, stoniness 0, slope < 0.2 %, no erosion risk of erosion or climatic limitations.

Table 7. *Soil LCC classes.*

	Area 1				Area 2				Area 3				Area 4				Area 5			
	2011		2016		2011		2016		2011		2016		2011		2016		2011		2016	
		LCC		LCC		LCC		LCC		LCC		LCC		LCC		LCC		LCC		LCC
Root restricting layer (m)	35	IV	>150	I	26	IV	>150	I	24	VII	>150	I	35	IV	>150	I	22	VII	>150	I
Texture	SL	II	SL	II	SL	II	L-SL	I - II	SL	II	SL	II	SL	II	SL	II	SL	II	SL	II
Parent material (%)	12	II	<5	I	18	III	<5	I	37	IV	<5	I	12	IV	<5	I	25	III	<5	I
Gravel (%)	6.5	IV	<0.3	I	5	IV	<0.3	I	28	VII	<0.3	I	6.2	IV	<0.3	I	6.8	IV	<0.3	I
Stoniness	no	I	no	I	no	I	no	I	no	I	no	I	no	I	no	I	no	I	no	I
Chemical fertility	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salinity (dS m^{-1})	0.2	I	0.8	I	0.3	I	2.8	II	2.0	I	2.4	II	0.2	I	1.4	II	0.1	I	2.7	II
Slope (%)	<0.2	I	<0.2	I	<0.2	I	<0.2	I	<0.2	I	<0.2	I	<0.2	I	<0.2	I	<0.2	I	<0.2	I
Erosion risk	no	I	no	I	no	I	no	I	no	I	no	I	no	I	no	I	no	I	no	I
Climatic limitation	no	I	no	I	no	I	no	I	no	I	no	I	no	I	no	I	no	I	no	I

Table 8. *Soil chemical fertility in LCC.*

	Area 1				Area 2				Area 3				Area 4				Area 5			
		LCC		LCC		LCC		LCC		LCC		LCC		LCC		LCC		LCC		LCC
pH	7.9	I	7.8	I	7.5	I	7.8	I	7.9	I	7.7	I	8.1	I	7.6	I	8.0	I	7.5	I
salinity (dS m^{-1})	0.2	I	0.8	I	0.3	I	2.8	II	2.0	I	2.4	II	0.2	I	1.4	II	0.1	I	2.7	I
C.E.C. (meq $100g^{-1}$)	19.7	I	31.2	I	12.1	I	34.5	I	8.5	I	33.0	I	32.2	I	41.0	I	15.9	I	37.0	I
$CaCO_3$ tot (g kg^{-1})	38	I	124	I	55	I	243	I	130	I	173	I	138	I	199	I	60	I	189	I

Soil is slightly alkaline pH 7.8; salinity is 2.8 dS m^{-1}; cation exchange capacity is 34.5 meq $100g^{-1}$; exchangeable potassium K_2O is 211 mg kg^{-1}; total limestone is 243 g kg^{-1}; organic carbon content is 6.6 %; phosphorus content P_2O_5 is 95 mg kg^{-1}. The texture is loamy, 10 % clay. Organic matter mineralized in 1 year is 0.9 %; complete mineralization of organic matter is 7.3 years.
In this area factors determining LCC class are texture and salinity: LCC class II, other parameters: LCC class I.

In FCC intrinsic fertility is class A, chemical fertility is class 2; total fertility is class I.

In area 3 roots restricting layer was > 150 cm, parent material < 5 %, gravel < 0.3 %, stoniness 0, slope < 0.2 %, no erosion risk or climatic limitations. Soil is slightly alkaline pH 7.7; salinity is 2.4 dS m^{-1}; cation exchange capacity is 33.0 meq $100g^{-1}$; exchangeable potassium K_2O is 284 mg kg^{-1}; total limestone is 173 g kg^{-1}; organic carbon content is 5.1 %; phosphorus content P_2O_5 is 85 mg kg^{-1}. The texture is loamy, 11 % clay. Organic matter mineralized in 1 year is 0.9 %; complete mineralization of organic matter is 3.1 years. In this area factors determining LCC class are texture and salinity: LCC class II, other parameters: LCC class I.

In FCC intrinsic fertility is class A, chemical fertility is class 2; total fertility is class I.

In area 4 roots restricting layer was > 150 cm, parent material < 5 %, gravel < 0.3 %, stoniness 0, slope < 0.2 %, no erosion risk or climatic limitations. Soil is slightly alkaline pH 7.6; salinity is 1.4 dS m^{-1}; cation exchange capacity is 41.0 meq $100g^{-1}$; exchangeable potassium K_2O is 183 mg kg^{-1}; total limestone is 199 g kg^{-1}; organic carbon content is 7.5 %; phosphorus content P_2O_5 is 121 mg kg^{-1}. The texture is loamy, 13 % clay. Organic matter mineralized in 1 year is 0.9 %; complete mineralization of organic matter is 8.3 years. In this area factors determining LCC class are texture and salinity: LCC class II, other parameters: LCC class I.

In FCC intrinsic fertility is class A, chemical fertility is class 2; total fertility is class I.

In area 5 roots restricting layer was > 150 cm, parent material < 5 %, gravel < 0.3 %, stoniness 0, slope < 0.2 %, no erosion risk or climatic limitations. Soil is slightly alkaline pH 7.5; salinity is 2.7 dS m^{-1}; cation exchange capacity is 37.0 meq $100g^{-1}$; exchangeable potassium K_2O is 206 mg kg^{-1}; total limestone is 189 g kg^{-1}; organic carbon content is 4.9 %; phosphorus content P_2O_5 is 133 mg kg^{-1}. The texture is loamy, 10 % clay. Organic matter mineralized in 1 year is 1.0 %; complete mineralization of organic matter is 3.3 years. In this area factors determining LCC class are texture and salinity: LCC class II, other parameters: LCC class I. In FCC intrinsic fertility is class A, chemical fertility is class 2; total fertility is class I.

Discussion and Conclusion

Analysing Table 9 and 10 it is clear that the restoration made by reconstitution have improved the agro-forestry conditions of the area (Figure 2). LCC and FCC classes changes from IV, VI and VII before to II LCC classes after restoration (class I: soils with slight limitation, class VII: soils with very severe limitations), and from C before to A FCC classes of total fertility after restoration (total fertility decreases from A to C).

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Table 9. *Soil FCC classes.*

	Area 1		Area 2		Area 3		Area 4		Area 5	
	2011	2016	2011	2016	2011	2016	2011	2016	2011	2016
Clay (%)	15	11	12	10	12	11	12	13	10	10
$CaCO_3$ tot (g kg^{-1})	38	124	55	243	130	173	138	199	60	189
Organic Carbon (%)	1.7	4.7	2.7	6.6	1.9	5.1	2.3	7.5	2.7	4.9
O.M. mineralized in 1 year (%)	1.5	1.0	1.5	0.9	1.1	0.9	1.1	0.9	1.5	1.0
Years for C mineralization (N)	1.1	4.5	1.8	7.3	1.7	3.1	2.1	8.3	1.7	3.3
pH	7.9	7.8	7.5	7.7	7.9	7.7	8.1	7.6	8.0	7.5
P_2O_5 (mg kg^{-1})	99	104	48	95	18	85	139	121	80	133
K_2O (mg kg^{-1})	82	199	95	211	98	284	99	183	82	206
Intrinsec fertility	C	A	C	A	C	A	B	A	C	A
Chemical fertility	3	2	3	2	5	2	3	2	3	2
Fertility	III	I	III	I	V	I	III	I	III	I

Table 10
Comparison of LCC classes.

LCC	Natural environment	Forest	Pasture			Farming			
			Limited	Moderate	Intensive	Limited	Moderate	Intensive	Very intensive
I									
II								Area: 1,2,3,4,5 2016	
III									
IV						Area: 1,5 2011			
V									
VI				Area: 2 2011					
VII			Area: 3,4 2011						
VIII									

Figure 2. *Closed landfill:* [A] *human transported material;* [B] *reconstituted soil;* [C] *natural vegetation on reconstituted soil.*

These results demonstrate how the reconstitution technology can convert the environmental and agronomic conditions from soil having severe limitation - due to poor vegetation and anthropogenic materials -, to a condition of moderate limitations. This change allowed to restore an abandoned area, lead to productivity and to environmental and forest prosperity. The soil improvements allow area to be a new ecosystem. In the area actually, they are planted more than 5000 species of native trees and shrubs to support revegetation and animal repopulation. Planting, already tried - before reconstitution - without any success, has been possible thanks to reconstituted soils properties, such as soil structure, high organic matter, increase root restricting layer, high fertility. These conditions wouldn't have been obtained only with soil tillage and fertilizations as many of the most important requirement to restore this area are unchangeable before reconstitution. The spontaneous recolonization occurred in the reconstituted soils (Figure 3) before planting gives evidence of fertility of reconstituted soils in comparison with human transported materials (Figure 4).

Figure 3. *Natural vegetation on reconstituted soil.*

Figure 4. *Natural vegetation on human transported material*.

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RECONSTITUTION: EVALUATION D'UNE INTERVENTION DE REAMENAGEMENT ENVIRONNEMENTAL EN ESTIMANT LA CAPACITE D'UTILISATION ET LA FERTILITE DU SOL

Résumé

La reconstitution est un pedotecnique qui produit Tecnosols, fertile et appropries environnemental, via utilisation de sédiments alluviales, sols dégrades et pedomaterialles comme ordures généré par différents activités productives. Biais de cette technologie, qui est un traitement chimique - mécanique des matrices utilisée, a été réalisée opérations de requalification environnementale dans un ex décharges pour les déchets solides urbains près Piacenza (LIFE10 ENV / IT / 000400 NEW LIFE) restaurer la couche supérior. Afin de représenter l'efficacité de cette restauration, on 5 stationnes de prélèvement ont été déterminés LCC et FCC classes, avant et après l'intervention. Les résultats de ces évaluations qui présent la transition des classes plus graves à cette meilleures tant pour LCC et FCC, montrent que la recostitution été capable de convertir les conditions ambiantes et agronomique d'une utilisation sporadique de pâturage à une possibilité d'agriculture intensive.

Mots-clés: *sol reconstitué, classification de la capacité d'utilisation, fertilité*

LA RICOSTITUZIONE: VALUTAZIONE DI UN INTERVENTO DI RIQUALIFICAZIONE AMBIENTALE MEDIANTE LA STIMA DELLA CAPACITÀ D'USO E DELLA FERTILITÀ DEL SUOLO

Riassunto

La ricostituzione è una pedotecnica che produce tecnosuoli, fertili ed idonei sotto l'aspetto ambientale, mediante l'utilizzo sedimenti alluvionali, suoli degradati e pedomateriali di differente origine tra i quali specifici rifiuti generati da differenti attività produttive. Mediante questa tecnologia, che consiste in un trattamento chimico - meccanico delle matrici impiegate, sono stati condotti interventi di riqualificazione ambientale in una ex discarica di rifiuti solidi urbani sita alle porte di Piacenza (LIFE10 ENV/IT/000400 NEW LIFE) ripristinandone lo strato superficiale. Al fine di rappresentare l'efficacia di tale ripristino, su 5 stazioni di campionamento sono state determinate la LCC e la FCC, prima e dopo l'intervento. Gli esiti di tali valutazioni, che mostrano il passaggio dalle classi peggiori a quelle migliori sia per LCC che per FCC, dimostrano come la ricostituzione sia stata in grado di convertire le condizioni ambientali ed agronomiche da un utilizzo di pascolo sporadico ad una possibilità di coltivazione intensiva.

Parole chiave: *suolo ricostituito, capacità d'uso, fertilità globale*

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